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The *Crassispora kosankei–Cystoptychus azcuyi* palynozone of the Upper Carboniferous Tupambi Formation, Tarija Basin, northern Argentina

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Abstract

Well-preserved and diverse palynomorph assemblages were recovered from surface and core samples from the middle to upper section of the Tupambi Formation. The latter is the basal unit of the Macharetí Group (Upper Carboniferous) of the Tarija Basin, northern Argentina. Assemblages are composed of trilete miospores, one hilate species, monosaccate pollen grains (one species striated), one praecolpate species and green algae (*Botryococcus*). Two key species are *Cystoptychus azcuyi* sp. nov. and *Crassispora kosankei* (Potonié and Kremp) Bharadwaj emend. Smith and Butterworth enable definition of the first palynozone for this basin. The age, as well as the biostratigraphic and paleogeographic significance of the palynoflora is discussed.

Keywords: miospores; systematic; biostratigraphy; Late Carboniferous; Tarija Basin; northern Argentina

1. Introduction

This paper is part of a wider investigation of Late Carboniferous palynomorph assemblages from the northern Argentinian Tarija Basin, which was initiated by Azcuy and Laffitte (1981), and extended by the author's Ph.D. studies (di Pasquo, 1999). Thus, the aims of this research are: (a) to describe and illustrate the two zonal species, one of them new, which are abundant in surface and core samples from the upper part of the Tupambi Formation; (b) to establish the first palynozone for this basin; and (c) to discuss the age and biostratigraphic and paleogeographic significance of the assemblage.

The Tarija Basin is an area of significant oil and gas resources. The Tupambi Formation, an essentially sandy unit, is an important reservoir. Therefore, its recognition and regional correlation in surface outcrop and in the subsurface is important and can be achieved palynologically.

2. Stratigraphy

Upper Carboniferous sediments outcrop in the Tarija Basin mainly in the Subandean Range but also in the eastern part of the Eastern Cordillera Range (Fig. 1). Extensive deposits occur in sub-

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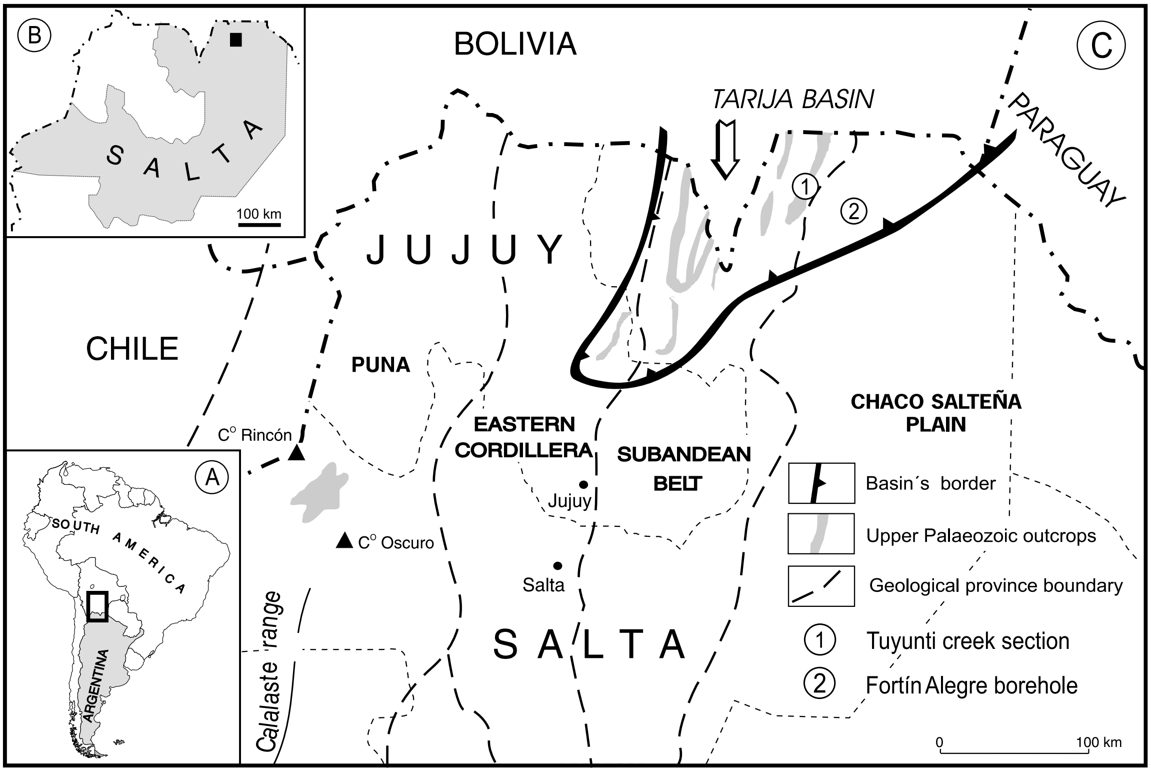


Fig. 1. Position of the Tarija Basin in South America. Location of the studied area in Salta Province, Argentina. Areal distribution of the Upper Paleozoic deposits in the Tarija Basin. The points 1 and 2 show the location of the sections palynologically studied.

surface of the Chacosalteña Plain (Villa et al., 1984; Belloti et al., 1995). They are separated by major unconformities into two major lithostratigraphic units, Macharetí and Mandiyutí Groups (Fig. 2B). The former disconformably overlies the Devonian Los Monos Formation while the latter is disconformably succeeded by the Upper Permian-Triassic (to Jurassic?) Cuevo Group or other younger units (Starck et al., 1993a). Both the Macharetí and Mandiyutí Groups are Upper Carboniferous upon the basis of palynological information (Azcuy and Laffitte, 1981; di Pasquo and Azcuy, 1997a,b, 1999a,b; Azcuy and di Pasquo, 1999, 2000; di Pasquo et al., 2001). Until now no systematic papers have previously been published on the Macharetí Group palynofloras.

The Macharetí Group in the Argentinian part of the basin reaches a maximum thickness of approximately 1000 m. It consists of the Tupambi, Itacuamí and Tarija Formations and underlies the Mandiyutí Group. The latter attains a maximum thickness of around 800 m, and includes the Escarpment and San Telmo Formations (Fig. 2B). The Tupambi Formation is essentially a sandy unit that contains some pelitic intercalation. It is conformable with the overlying Itacuamí Formation, which is mainly composed of dark to grey greenish pelites, in tabular layers with parallel lamination and minor sandy intercalations. The Tarija Formation is the thickest and the most representative unit of the Macharetí Group. It is composed mainly of stratified or massive diamictites that alternate mainly with dark grey to black pelite layers in the basal part of the unit; toward the top, lenticular bands of sandstone (fine- to very coarse-grained) are intercalated.

3. Materials and methods

3.1. Provenance of samples

The Tuyunti Creek section outcrops 4 km southwest of Aguaray in the Aguaragüe Range (Fig. 1) and begins with small exposures (around 5 m thick) of the upper Tupambi Formation, disconformably overlying Recent deposits through reverse faulting. It is composed of two sets of grey sandstone beds which alternate with thin-bedded grey shales and diamictites from where two samples (BAFC-Pl 453 and 451) were collected in 1986 (Fig. 2A). Other samples collected in 1978 by Azcuy and Laffitte from the same outcrop (Fig. 2A) are restudied herein. Only preliminary palynological results have previously been published, i.e. unillustrated lists of species (Azcuy and Laffitte, 1981).

The other section from the borehole Fortín Alegre (S-F.A. x-1) is located near Tonono on the Chacosalteña plain. It was drilled by YPF Company in 1969 (Figs. 1 and 2A). Villa et al. (1984), in a subsurface stratigraphic study of the Tupambi Formation from northern Argentina, divided this unit informally into three members (Fig. 2B), based on lithologic criteria. The correlation of different subsurface sections suggested important lithofacies and thickness changes. The basal or 'lower sandy' member has a restricted areal distribution, confined to areas of maximum subsidence. Where the basement is elevated this member is absent or extremely reduced. It is composed of sandstones and wackestones. The maximum thickness is 300 m, developed in the central part of the Durán Field. In the Fortín Alegre borehole this basal member extends from 2856 to 2970 m. The sample BAFC-Pl 1264 (2975 m) yielded a badly preserved assemblage of probable Late Devonian age (Fig. 2A).

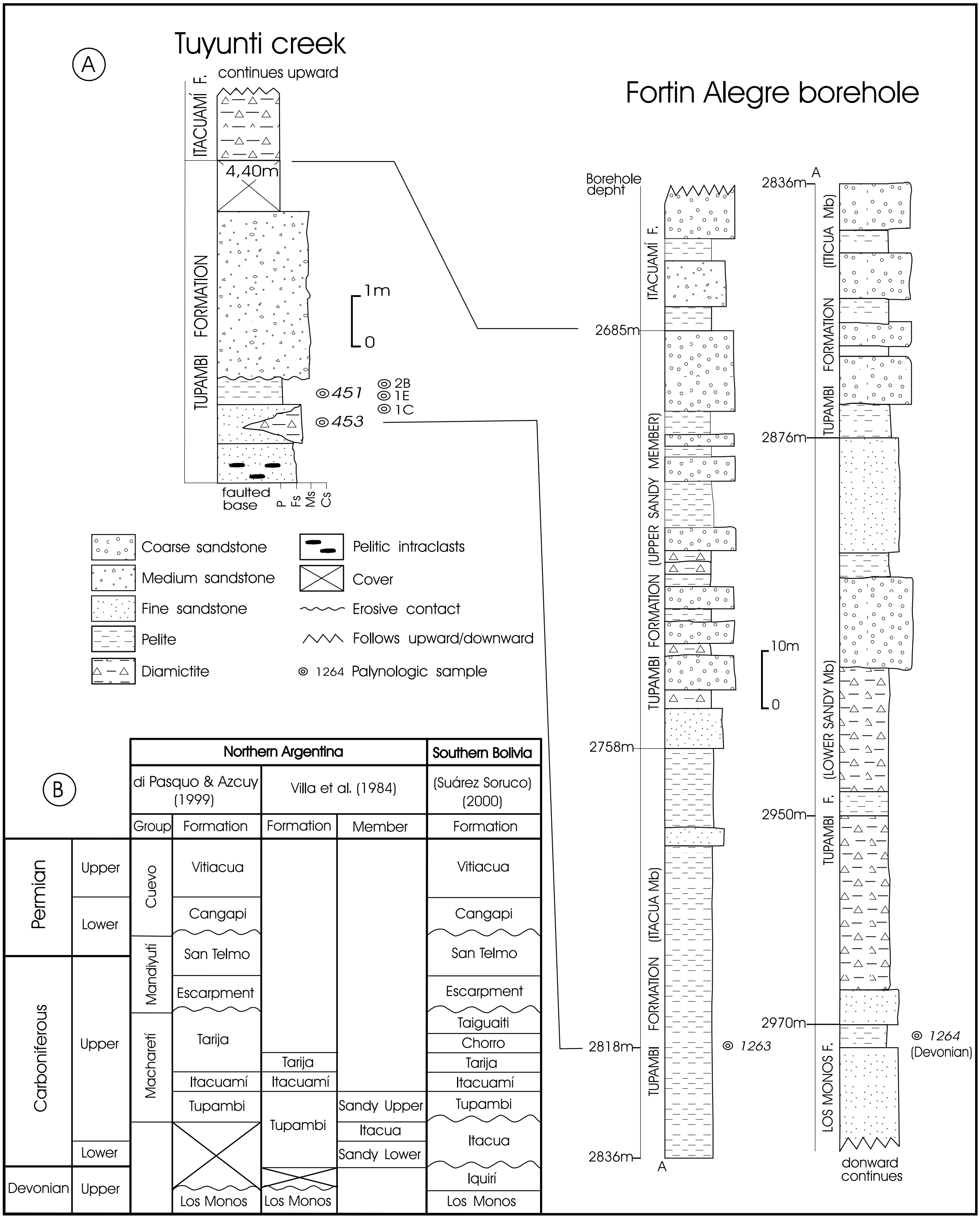
The overlying members have greater areal distribution, representing infilling of pre-existing depressions by onlapping units. The following 'pelitic or Itacua' member is composed almost entirely of black shales and siltstones with some intercalations of fine- to medium-grained sandstones. In the central Durán Field this member is completely absent, thus precluding differentiation of the lower and upper sandy members. To the north and south of that area, the member rests directly on Devonian rocks. Because the member is lithologically similar to the Itacua Formation in Bolivia, Villa et al. (1984) correlated the basal and middle members described above with the Bolivian Itacua Formation, which has been thought to be absent in the Argentinian Tarija Basin (Fig. 2B). Based on previous palynologic studies, the Itacua Formation (and equivalent units) is assigned to the Early Carboniferous in Bolivia (see di Pasquo and Azcuy, 1997b). On the other hand, in Argentina, the Upper Carboniferous Macharetí and Mandiyutí Groups have yielded reworked Devonian to Early Carboniferous palynomorphs suggesting the prior existence of rocks representing that interval (see Appendix 1; di Pasquo and Azcuy, 1997b). The sample BAFC-Pl 1263, of the 'pelitic or Itacua' member, consists of black thin-bedded shale obtained from a corehole at 2818 m. This level 133 m below the inferred boundary between Itacuamí and Tupambi Formations (Fig. 2A), has yielded one of the palynofloral assemblages studied herein, considered to be early Late Carboniferous (≅Namurian-Westphalian).

Finally, the 'upper sandy' member, between 2758 and 2685 m, is mainly composed of white sandstones of variable grain size and of variable thickness (0–250 m, with maximum at the western Campo Durán: Villa et al., 1984).

3.2. Laboratory study

Shale samples were processed using standard procedures previously described (e.g. Playford, 1977). The organic residue was screened through a 25-μm mesh and the +25-μm fraction used for preparing the slides mounted in glycerine jelly. All materials, including the slides, are stored with the prefix BAFC-Pl in the repository of the Palynology Laboratory at the Geology Department of the Buenos Aires University, Argentina.

Conventional light microscopy was performed with an Orthoplan Leitz No. 4303017 binocular microscope equipped with an Orthomat Leitz photomicrograph camera. An England Finder slide was used to locate the palynomorphs.


A
Tuyunti creek
continues upward
ITACUAMÍ F.
4,40m
TUPAMBI FORMATION
1m
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451
453
2B
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faulted base
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Fs
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Coarse sandstone
Medium sandstone
Fine sandstone
Pelite
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Cover
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Follows upward/downward
1264 Palynologic sample
Fortin Alegre borehole
Borehole depht
ITACUAMÍ F.
2685m
TUPAMBI FORMATION (UPPER SANDY MEMBER)
2758m
TUPAMBI FORMATION (ITACUA Mb)
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TUPAMBI F. (LOWER SANDY Mb)
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1264 (Devonian)
LOS MONOS F.
donward continues
B
Northern Argentina
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di Pasquo & Azcuy (1999)
Villa et al. (1984)
(Suárez Soruco) (2000)
Group
Formation
Formation
Member
Formation
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Upper
Lower
Carboniferous
Upper
Lower
Devonian
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Cuevo
Mandiyutí
Machareti
Vitiacua
Cangapi
San Telmo
Escarpment
Tarija
Itacuamí
Tupambi
Los Monos
Tarija
Itacuamí
Tupambi
Los Monos
Sandy Upper
Itacua
Sandy Lower
Vitiacua
Cangapi
San Telmo
Escarpment
Taiguaiti
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Tarija
Itacuamí
Tupambi
Itacua
Iquirí
Los Monos

Specimen preparation for the scanning electron microscope (SEM) followed the conventional time-consuming hand-picking method from an aqueous solution under a binocular microscope. Picked specimens were mounted on a glass coverslip that was fixed to the aluminium stub with an easily removable adhesive and then the gold coating was applied. SEM utilised a Leitz AMR 1200 instrument with 15 kV energy and Ilford FP4 black/white film for photographic illustration.

Like Zippi (1991), who proposed a method for same-specimen study with SEM and a light microscope (LM), the author tried to observe the same specimens under the LM after the SEM study. The coverslip was prised from the aluminium stub and mounted in an inverted position onto a glass slide with glycerine jelly. Although it was possible to recognize the same specimen under the LM that had been photographed with the SEM, the gold coating prevented adequate LM photomicrography. Nevertheless, it was useful because of the observation of internal characters not seen with SEM, which lends accuracy to the identification of species. One specimen is figured with both LM and SEM as an example (see Plate II, 14 and 18).

4. Systematic palynology of selected taxa

The Potonié (1956, 1958, 1960, 1970) suprageneric classification together with the Dettmann (1963) modifications to certain suprageneric categories and the Dibner (1971, 1973) infraturma scheme for monosaccate pollen grains are followed in the taxonomic section. The descriptive terminology applied is based on Kremp (1974) and Punt et al. (1994). The validation of morphologic features and criteria used in the monosaccate pollen grains classification presented by Azcuy and di Pasquo (2000) is accepted herein. For this reason, the monosaccate species were not included in the systematic section but only in Table 2 and Appendix 1. The description of certain taxa widely known in the literature was not mentioned. Only their occurrences are cited and moreover a few monosaccate species are figured. A complete palynomorphs list including recycled palynomorphs, with authors citation is found in Appendix 1.

Anteturma **Proximegerminantes** Potonié 1970
Turma **Triletes** Reinsch emend. Dettman 1963
Suprasubturma **Acavatriletes** Dettman 1963
Subturma **Azonotriletes** (Luber) Dettman 1963
Infraturma **Laevigati** (Bennie and Kidston) Potonié 1970

Genus ***Calamospora*** Schopf, Wilson and Bentall 1944

Type species: *Calamospora hartungiana* Schopf in Schopf, Wilson and Bentall 1944.
Botanical affinity: Pteridophyta-Filicopsida (Eggert and Taylor, 1966; Laveine, 1969). Sphenophyta (Potonié, 1962; Boureau, 1964; Courvoisier and Phillips, 1975; Coquel and Brousmiche Delcambre, 1996), Noeggerathiales (Leary, 1980). See also Balme (1995, p. 249).

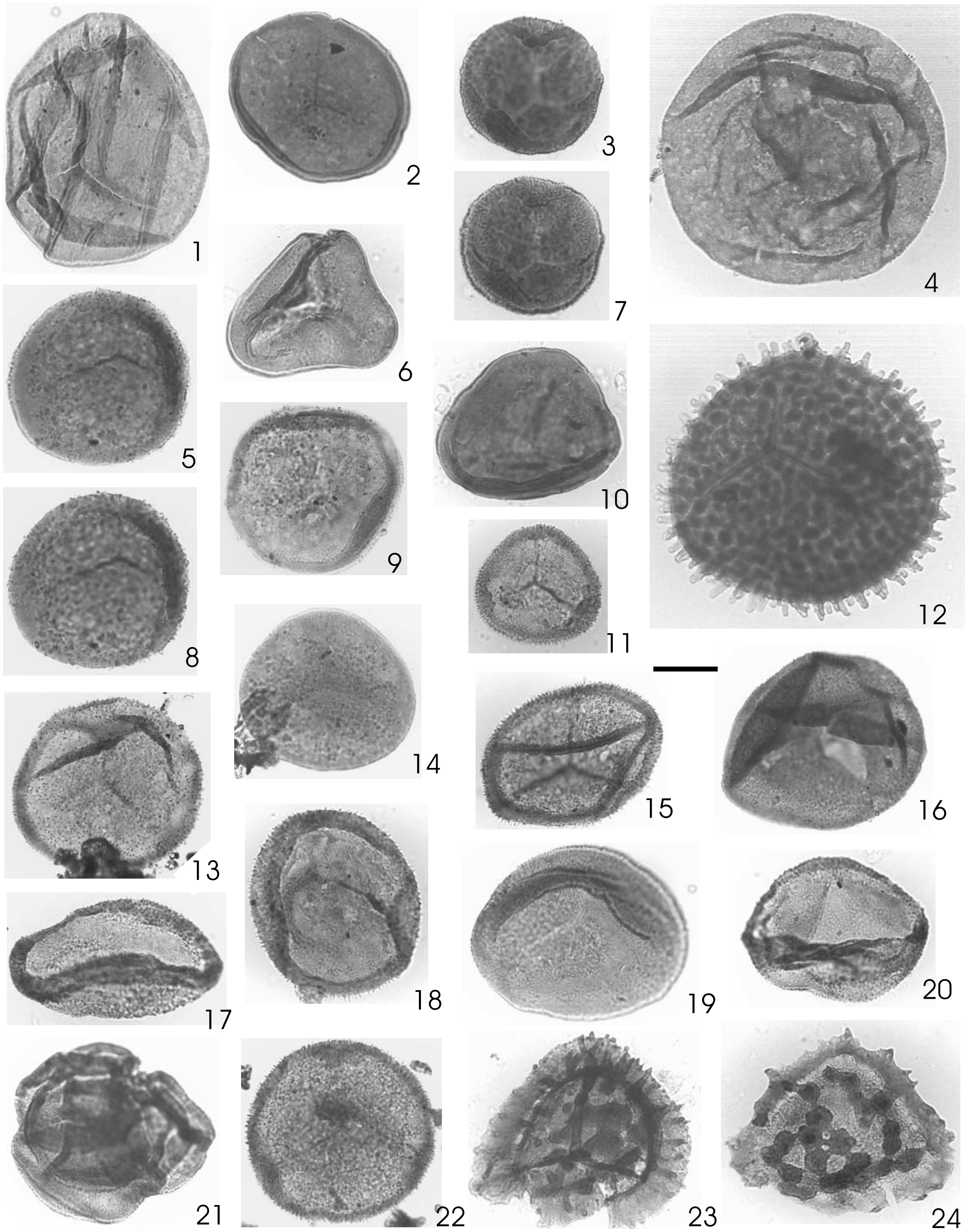
Calamospora hartungiana Schopf in Schopf, Wilson and Bentall 1944 (Plate I, 1, 4)
Distribution: This is a common component of Late Carboniferous–Lower Permian worldwide microfloras.

Genus ***Waltzispora*** Staplin 1960

Type species: *Waltzispora lobophora* Staplin, 1960.
Botanical affinity: unknown.

Waltzispora polita (Hoffmeister, Staplin and Malloy) Smith and Butterworth 1967 (Plate I, 6)
Distribution: Mississippian, USA (Hoffmeister et al., 1955). Visean/Namurian, Poland (Jachowicz, 1964), England (Butterworth and Williams, 1958;

Fig. 2. (A) Generalised representation of the two palynological studied sections, one at left from Tuyunti Creek and the other on the right, from the Fortín Alegre borehole. Correlation between samples is also shown. (B) Chronostratigraphy of the Tarija Basin between northern Argentina and southern Bolivia Subandean Belt.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Sullivan and Marshall, 1966; Smith and Butterworth, 1967). Early Late Carboniferous (≅Namurian-Westphalian), Argentina (Menéndez and Azcuy, 1969; González Amicón, 1973; di Pasquo, 1999), USA (Felix and Burbridge, 1967; Urban, 1971). Late Carboniferous, Australia (Playford and Powis, 1979), Brazil (Playford and Dino, 2000a). Carboniferous, Libya (Loboziak and Clayton, 1988). Namurian, Saudi Arabia (Clayton, 1995). Westphalian D-Stephanian, Oman and Saudi Arabia (Stephenson and Filatoff, 2000). See also other records in Playford (1991, p. 93).

Genus ***Punctatisporites*** Ibrahim emend. Potonié and Kremp 1954

Type species: *Punctatisporites punctatus* Ibrahim 1933.
Botanical affinity: See Balme (1995).

Punctatisporites glaber (Naumova) Playford 1962 (Plate I, 2)

Distribution: Early Late Carboniferous (≅Namurian-Westphalian), Argentina (Menéndez and Azcuy, 1969, 1973; Azcuy, 1975a; Limarino and Gutiérrez, 1990; Ottone, 1989, 1991; di Pasquo, 1999). Late Serpukhovian, Libya (Coquel et al., 1988). See other world records in Azcuy (1975a, p. 24).

Infraturma **Retusotrileti** Streel 1964

Genus ***Apiculiretusispora*** Streel 1964

Type species: *Apiculiretusispora brandtii* Streel, 1964.
Botanical affinity: See Traverse (1988) and Balme (1995).

Apiculiretusispora alonsoi Ottone 1989 (Plate I, 3, 7)
Remarks: This species differs from others of the genus due to the presence of subordinated capilli between coni and spinae.

Plate I. Selected miospores from *Crassispora kosankei–Cystoptychus azcuyi* palynozone. All photographs ×500. Bar scale: 22 μm.

1, 4.	*Calamospora hartungiana* Schopf in Schopf, Wilson and Bentall.
1.	BAFC-Pl 451(2) Z52/2-4.
4.	BAFC-Pl 1E(04) D31/1.
2.	*Punctatisporites glaber* (Naumova) Playford. BAFC-Pl 1C(4) N43/3.
3, 7.	*Apiculiretusispora alonsoi* Ottone. BAFC-Pl 451(2) C48/1.
5, 8, 9.	*Granasporites medius* (Dybová and Jachovicz) Ravn et al.
5.	Proximal focus. BAFC-Pl 1C(4) W24/1.
8.	Same as 5, distal focus.
9.	Distal focus. BAFC-Pl 1E(04) B29/0.
6.	*Waltzispora polita* (Hoffmeister, Staplin and Malloy) Smith and Butterworth. BAFC-Pl 451(5) B39/2.
10.	*Granulatisporites parvus* (Ibrahim) Schopf, Wilson and Bentall. BAFC-Pl 453(4) G27/1.
11.	*Raistrickia* sp. cf *R. crinita* Kosanke. BAFC-Pl 1E(04) T50/1.
12, 14, 15, 17, 18, 20, 21, 22.	*Crassispora kosankei* Potonié and Kremp) Bhardwaj emend. Smith and Butterworth.
12.	BAFC-Pl 1E(04) H33/0.
14.	BAFC-Pl 451(1) W43/0.
15.	BAFC-Pl 451(3) G25/4.
17.	BAFC-Pl 451(2) J58/0.
18.	BAFC-Pl 451(1) Z48.
20.	BAFC-Pl 451(3) A44/0.
21.	BAFC-Pl 451(2) S28/1.
22.	BAFC-Pl 1E(26) L35/3.
13.	*Granulatisporites varigranifer* Azcuy. BAFC-Pl 1E(04) L48/3.
16.	*Apiculatasporites caperatus* Menéndez and Azcuy. BAFC-Pl 1E(04) F30/1.
19.	*Apiculatasporites parviapiculatus* Azcuy. BAFC-Pl 451(5) P34/1.
23.	*Cristatisporites rollerii* Ottone. BAFC-Pl 453(5) V30/4.
24.	*Cristatisporites stellatus* (Azcuy) Limarino and Gutiérrez. BAFC-Pl 451(2) Z32/0.

Distribution: Late Carboniferous, Argentina (Ottone, 1989, 1991; García, 1995; di Pasquo, 1999).

Infraturma **Apiculati** (Bennie and Kidston) Potonié 1956
Subinfraturma **Granulati** Dybová and Jachowicz 1957

Genus ***Granasporites*** Alpern emend. Ravn, Butterworth, Phillips and Peppers 1986

Type species: *Granasporites medius* (Dybová and Jachowicz) Ravn, Butterworth, Phillips and Peppers 1986.
Botanical affinity: Lycopsida (see Ravn et al., 1986; Lyons et al., 1997).

Granasporites medius (Dybová and Jachovicz) Ravn, Butterworth, Phillips and Peppers 1986 (Plate I, 5, 8)
Description: Trilete spore, acavate, amb circular to rounded triangular. Trilete mark simple, very faint to indistinct; rays straight extend two thirds to three quarters of spore radius, sometimes terminating with incomplete curvaturae. Proximal surface (contact areas) scabrate or with scarce grana. Distal surface and equator ornamented with small grana, circular to subcircular in polar view. The distribution and density of ornamentation is highly variable, from very dense to sparse. In one specimen the distribution is also variable, arranged into loose groups or clumps. Exinal folds are commonly present.
Dimensions (75 specimens): Equatorial diameter 54(55–66)87 μm; grana 1–1.5–1.8 μm diameter (scarce specimens present larger grana 2.3 μm diameter); exine thickness 2–2.5 μm.
Remarks and comparisons: It is noted that some specimens have subordinated pila and bacula between grana. This species differs from the ones assigned to *Cyclogranisporites* Potonié and Kremp mainly in possessing the proximal face (contact areas) smooth or with scarce grana.
Distribution: This species is for the first time recorded in the early Late Carboniferous (≅Namurian-Westphalian, Morrowan or early Bashkirian) but it has already been reported in the Stephanian of Argentina (di Pasquo et al., 2001). It is an abundant constituent of miospore floras from the Late Carboniferous of Europe and the Lower and Middle Pennsylvanian of North America (Ravn et al., 1986).

Genus ***Granulatisporites*** (Ibrahim) Potonié and Kremp 1954

Type species: *Granulatisporites granulatus* Ibrahim 1933.
Botanical affinity: Sphenopsida (Schopf et al., 1944). Pterydophyta, Filicopsida (Potonié and Kremp, 1956; Potonié, 1962; Grauvogel-Stamm and Doubinger, 1975; Millay and Taylor, 1982; Brousmiche, 1986). Pteropsida (Rothwell, 1976). Pteridospermophyta, Lyginopteridales (Millay and Taylor, 1979). See also Balme (1995).
Granulatisporites parvus (Ibrahim) Schopf, Wilson and Bentall 1944 (Plate I, 10).

Distribution: Westphalian, Germany (Ibrahim, 1933). Westphalian B, Canada (Barss, 1967). Late Carboniferous, Argentina (Azcuy, 1975a; di Pasquo and Azcuy, 1997a; di Pasquo, 1999). See additional records in Azcuy (1975a, p. 35).

Granulatisporites varigranifer Menéndez and Azcuy 1971 (Plate I, 14)
Distribution: Late Carboniferous, Argentina (Menéndez and Azcuy, 1971; González Amicón, 1973; Azcuy, 1975a; Menéndez and González Amicón, 1979; Ottone, 1989; García, 1995; di Pasquo and Azcuy, 1997a; di Pasquo, 1999). Westphalian-Stephanian, Brazil (Souza, 1997).

Subinfraturma **Nodati** Dybová and Jachowicz 1957

Genus ***Apiculatasporites*** (Ibrahim) Smith and Butterworth 1967

Type species: *Apiculatasporites spinulistratus* (Loose) Ibrahim 1933.
Botanical affinity: Filicales? (Potonié, 1962). Progymnosperm (Tschudy and Scott, 1969; Pfefferkorn et al., 1971).

Apiculatasporites caperatus Menéndez and Azcuy 1969 (Plate I, 16)
Comparisons: This species differs from *A. daemonii* Playford and Dino 2000a, recently described for the Late Carboniferous of Amazonas Basin (Brazil), in having a lipped trilete, contact areas less sculptured to unsculptured and the presence of basally fused coni between others which are discrete.
Distribution: Late Carboniferous, Argentina (Menéndez and Azcuy, 1969; González Amicón, 1973; Azcuy, 1975a; Vergel et al., 1993; García, 1995; di Pasquo and Azcuy, 1999a; di Pasquo, 1999).

Apiculatasporites parviapiculatus Azcuy 1975 (Plate I, 19)
Comparisons: This species differs from *A. caperatus* Menéndez and Azcuy in its smaller size coni (up to 1 μm) and denser distribution of the ornaments.
Distribution: Late Carboniferous, Argentina (Azcuy, 1975a; Limarino and Gutiérrez, 1990; Ottone and Azcuy, 1990; García, 1995; di Pasquo, 1999).

Subinfraturma **Baculati** Dybová and Jachowicz 1957

Genus ***Raistrickia*** Schopf, Wilson and Bentall emend. Potonié and Kremp, 1954

Type species: *Raistrickia grovensis* Schopf Wilson and Bentall 1944.
Botanical affinity: Filicopsida (Potonié and Kremp, 1956; Andrews et al., 1970), Pecopteridales (Laveine, 1969; Grauvogel-Stamm and Doubinger, 1975). See also Balme (1995).

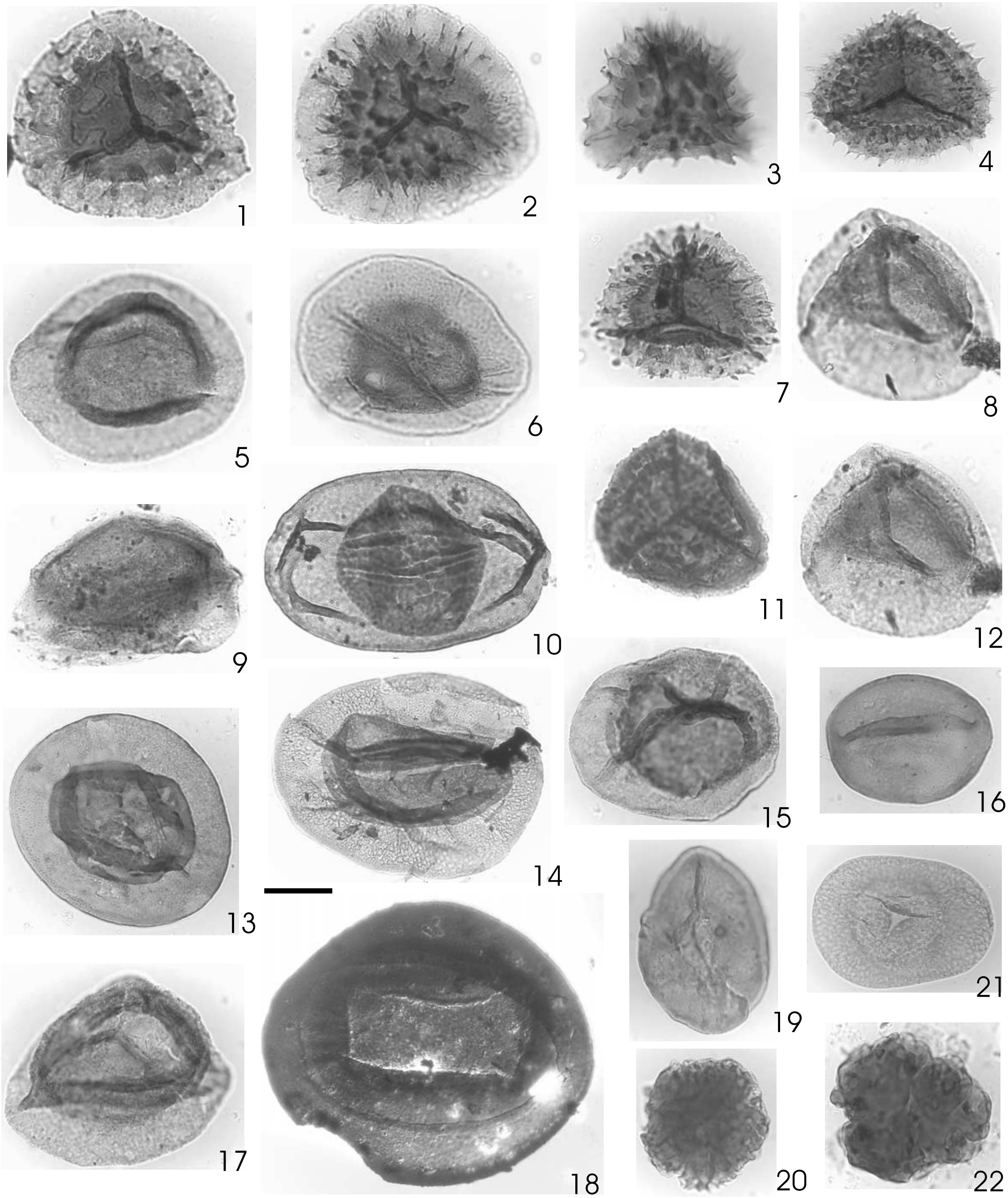
Raistrickia sp. cf. *R. crinita* Kosanke 1950 (Plate I, 12)
Dimensions (one specimen): Equatorial diameter 96.3 μm; sculptural projections (bacula and truncated coni) 7.5–9.5 μm length and 5 μm maximum basal diameter.
Comparisons: The specimen illustrated (Plate I, 11) is comparable to the original material described from Illinois (Kosanke, 1950), except for having a denser sculpture and being a little larger. More specimens are necessary to be recovered in order to make an accurate designation.
Distribution: Pennsylvanian, USA (Kosanke, 1950; Peppers, 1970). Westphalian C, Canada (Barss, 1967). It is the first record in the early Late Carboniferous (≅Namurian-Westphalian) of Argentina.

Suprasubturma **Laminatitriletes** Smith and Butterworth 1967
Subturma **Zonolaminatitriletes** Smith and Butterworth 1967
Infraturma **Crassiti** Bharadwaj and Venkatachala emend. Smith and Butterworth 1967

Genus ***Crassispora*** Bhardwaj emend. Keegan and Penney 1978

Type species: *Crassispora kosankei* (Potonié and Kremp) Bhardwaj 1957b emend. Smith and Butterworth, 1967. Smith and Butterworth (1967) consider *Crassispora ovalis* (Bhardwaj) Bhardwaj, 1957b (by original designation) a junior synonym of *C. kosankei*.
Botanical affinity: Lycophyta, Sigillariaceae (Smith and Butterworth, 1967; Phillips, 1979; Balme, 1995; Lyons et al., 1997).
Remarks: This genus includes circular to rounded triangular camerate spores with an equatorial crassitude. Distal and equatorial surfaces ornamented with small apiculati elements; laevigate contact areas; trilete mark, often indistinct, with ray folds and curvaturae (Keegan and Penney, 1978).

Crassispora kosankei (Potonié and Kremp) Bhardwaj emend. Smith and Butterworth 1967 (Plate I, 11, 13, 15, 17, 18, 20, 21, 22)
For synonymy see Smith and Butterworth (1967, p. 234).
Basionym: *Planisporites kosankei* Potonié and Kremp 1955, pl. 13, fig. 208.
Type locality: Ruhr Coalfield, Germany (Westphalian B).
Amplification of diagnosis: Radial, trilete, camerate. Amb subcircular, oval or rounded triangular. Margin conate to spinose. Intexine indistinct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because it is closely adpressed to exoexine but sometimes may be slightly separated. Trilete mark rarely distinct, simple, straight, sometimes bordered by ray folds, extending 2/3–3/4 of spore radius. Subequatorial crassitude, 1/5(1/6)1/8 wide, darker than polar regions, often of variable width when it is connected with curvaturae. Distal surface and proximal-equatorial region sculptured with discrete, taper-pointed coni, mammillate coni and spines, spacing variable from dense to sparsely distributed between specimens. Generally, the separation between elements is from 1 to 3 basal diameters. Proximal face thin, with scattered ornament or laevigate in contact areas. Exine finely punctate to microgranulate, 1–2-μm thickness, frequently folded. Lateral compressions are common.

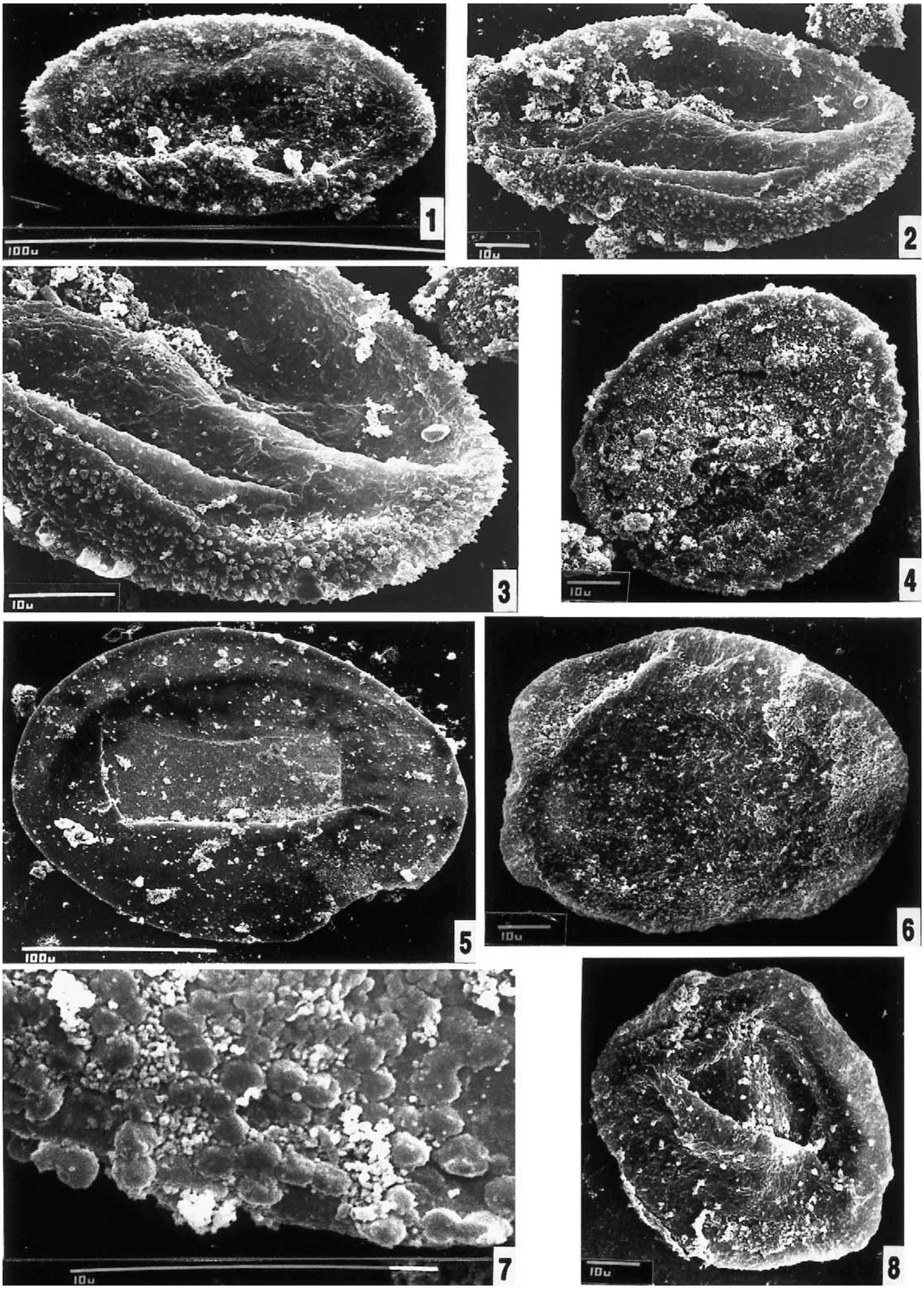
Dimensions (90 specimens): Major equatorial diameter 45(55–65)80; cones 0.6–1.2 μm height and breadth; spines 0.5–0.8 μm breadth, 0.8(1.2)1.5 μm height (rarely up to 2.3 μm); crassitude width 2.3(3.5–4.5)6 μm.

Remarks: The presence of curvaturae connecting the crassitude on the proximal surface, the dimensions of spines and a closely spaced distribution of ornamentation observed in many specimens, allow amplification of the diagnosis. Apical papillae are frequently not seen though many specimens lack preservation of the contact areas. SEM specimens illustrated on Plate III, 1–3, show apiculate equatorial ornamentation, laevigate contact areas, curvaturae related with crassitude and a finely micropunctate-microgranulate exine. The cameration is not always visible.

Comparisons: This is an abundant species in the Tupambi Formation from Tarija Basin in Argentina. Most Argentinian specimens are morphologically similar to others from Europe and USA microfloras but some have larger and denser ornamentation. So, in this assemblage, these features show a continuously size gradation among specimens. The equatorial crassitude, the apiculate ornamentation without capilli and the quite variable amb (from rounded triangular to oval),

Plate II. Selected miospores from *Crassispora kosankei-Cystoptychus azcuyi* palynozone. Photographs 10, 13, 14, 16, 21 ×250; scale bar: 44 μm. The other photographs ×500. Bar scale: 22 μm.

1:	*Cristatisporites rollerii* Ottone. BAFC-Pl 451(2) T57/0.
2, 7.	*Kraeuselisporites volkheimerii* Azcuy.
2.	BAFC-Pl 451(2) H38/3.
7.	BAFC-Pl 451(5) P42/3.
3.	*Cristatisporites saltitensis* Ottone. BAFC-Pl 451(5) E38/1.
4.	*Cristatisporites* sp. B Archangelsky and Gamerro. BAFC-Pl 451(5) A30/2.
5, 6, 8, 9, 12, 15, 17.	*Cystoptychus azcuyi* sp. nov.
5.	Paratype, proximal focus, BAFC-Pl 451(1) B54/2.
6.	Holotype, proximal focus, BAFC-Pl 451(2) U30/0.
8.	Distal focus, BAFC-Pl 451(5) Z30/2.
9.	Paratype in lateral view, BAFC-Pl 453(4) J58/0.
12.	Idem 8 in proximal focus.
15.	Proximal focus, BAFC-Pl 451(1) K29/0.
17.	Proximal focus, BAFC-Pl 451(1) C33/4.
11.	*Vallatisporites vallatus* Hacquebard. BAFC-Pl 451(5) X34/4.
13.	*Potonieisporites neglectus* Potonié and Lele. BAFC-Pl 451(5) R35/4.
14, 18.	*Potonieisporites novicus* Bhardwaj emend. Poort and Veld.
14.	BAFC-Pl BAFC-Pl 451(5) Y31.
18.	Same specimen illustrated in PLATE III, 5, but figured with light-microscopy after being done with [sem].
16.	*Schopfipollenites ellipsoides* (Ibrahim) Potonié and Kremp. BAFC-Pl 451(5) H51.
19.	*Psomospora detecta* Playford and Helby. BAFC-Pl 451(5) S35/0.
20, 22.	*Botryococcus braunii* Kützing.
20.	BAFC-Pl 451(5) X51/0.
22.	BAFC-Pl 453(5) V30/0.
21.	*Schulzospora* sp. BAFC-Pl 451(2) C54/0.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permit the distinguishing of *C. kosankei* from *Apiculiretusispora alonsoi* Ottone 1989. *Crassipora maculosa* (Knox) Sullivan 1964 is distinguished by its more variable ornamentation which includes small warts and grana between coni and spines and a wider equatorial crassitude.
Distribution: First mention in the early Late Carboniferous of Argentina. Westphalian B, Germany (Potonié and Kremp, 1955). Westphalian C-D, Germany (Bhardwaj, 1957a,b), Saudi Arabia (Owens and Turner, 1995). Above Namurian B (Dybová and Jachowicz, 1957). Namurian B, England (Neves, 1961). Westphalian A, England (Sullivan, 1964). Westphalian D, USA (Habib, 1966). Namurian-Westphalian D, England (Smith and Butterworth, 1967). Namurian B-Westphalian D, Western Europe (Clayton et al., 1977). Namurian A/B-Westphalian, Russia (Owens et al., 1978). Westphalian A-C, The Netherlands (Van de Laar and Fermont, 1989). Westphalian D - Stephanian A, Northwest Spain (Coquel and Rodríguez, 1995). Westphalian, Canada (Lyons et al., 1997).

Infraturma **Cingulicavati** Smith and Butterworth 1967

Genus ***Cristatisporites*** (Potonié and Kremp) Butterworth, Jansonius, Smith and Staplin 1964

For synonymy see Playford (1971, 1978) and McGregor and Camfield (1982).
Type species: *C. indignabundus* (Loose) Potonié and Kremp, 1954.
Botanical affinity: Lycophyta (Chaloner, 1962; Leisman, 1970; Césari and Gutiérrez, 1986; Balme, 1995; Coquel and Brousmiche Delcambre, 1996).

Cristatisporites rollerii Ottone 1989 (Plate I, 23, Plate II, 1)
Dimensions (eight specimens): Equatorial diameter 60–82 μm.
Remarks: A laevigate proximal face; distal polar surface sculptured with sinuous mammillate ridges or cristae; a narrow cingulum with baculate-type ornament and large spines and a lesser ornamented zone with sparse small apiculate elements that are also visible at the margin of the spore distinguish this species from others of the genus. The boundary between the cingulum and the outer zone is marked by small vacuoles.
Distribution: Late Carboniferous, Argentina (Ottone, 1989, 1991; Vergel et al., 1993; Césari and Bercowski, 1997; di Pasquo and Azcuy, 1999a; di Pasquo, 1999).

Cristatisporites stellatus (Azcuy) Limarino and Gutiérrez 1990 (Plate I, 24)

1980 *Kraeuselisporites* sp. Archangelsky and Gamerro, pl. 1, fig. 5.
1999 *Densosporites stellatus* Azcuy; di Pasquo and Azcuy, pl. 1, fig. 5.

Dimensions (five specimens): Equatorial diameter 70–75 μm.
Remarks: A thick cingulizonate structure bears discrete coni, spinae and mammillate elements.

Plate III. SEM images.

1, 2, 3.	*Crassispora kosankei* (Potonié and Kremp) Bhardwaj emend. Smith and Butterworth.
1.	Showing curvaturae on proximal face and apiculate ornamentation on equatorial margin.
2.	Showing the laesurae elevated on the sunken proximal face and proximal-equatorial and ornamentation.
3.	Idem 2 with detail of coni.
4, 7.	*Granasporites medius* (Dybová and Jachovicz) Ravn et al.
4.	Distal face with granulate ornamentation.
7.	Detail of the grana.
5.	*Potonieisporites novicus* Bhardwaj emend. Poort and Veld., showing the distal face.
6, 8.	*Cystoptychus azcuyi* sp. nov.
6.	Distal face shows only the outer lamella.
8.	Proximal face showing folds near central body periphery.

A narrow vacuolate zone separates the cingulum from thinner polar surfaces. Distal exine bears a prominent biform sculpture with some discrete, low and coarse mammoid verrucae that are mainly fused to form sparse sinuous cristate elements. Sometimes the latter elements may delimit broad lumina. Proximal face laevigate or slightly granulose. Laesurae distinct or indistinct, simple and short reaches only the inner margin of the cingulizonate structure.
Comparisons: The specimen illustrated as *Kraeuselisporites* sp. by Archangelsky and Gamerro (1980; pl. 1, fig. 5) from the Lower Permian of Colorado Basin (Buenos Aires Province, Argentina), is morphologically very similar so it is considered a junior synonym of *C. stellatus*.
Distribution: Late Carboniferous, Argentina, Paganzo Basin (Azcuy, 1975b; Limarino and Gutiérrez, 1990; Vergel and Luna, 1992; di Pasquo and Azcuy, 1997a, 1999a; di Pasquo, 1999). Early Permian, Argentina, Colorado Basin (Archangelsky and Gamerro, 1980).

Cristatisporites saltitensis Ottone 1989 (Plate II, 3)
Dimensions (one specimen): Equatorial diameter 58 μm; major elements up to 9 μm long, up to 6 μm basal width.
Remarks: Thin zone with irregular margin, bearing small spines, coni and verrucae; cingulum sculptured with mainly discrete biform elements (cylindrical or subconical forms that taper to very narrow spinose tips). Distal face and proximal equatorial area bear galeae and mammelliform elements sometimes basally fused. Proximal face laevigate; trilete mark accompanied by elevated lips. These are the main characteristics that distinguish this form from others of the genus.
Distribution: Early Late Carboniferous (≅ Westphalian), Argentina (Ottone, 1989).

Cristatisporites sp. B Archangelsky and Gamerro 1979 (Plate II, 4)
Dimensions (two specimens): Equatorial diameter 58–60 μm, major elements 4–7 μm.
Remarks and comparisons: The recorded specimens display, as described by Archangelsky and Gamerro (1979), a cingulizonate structure with a prominent apiculate margin separated from the intexinal body by a narrow, sometimes vacuolate space. Trilete mark bearing spinose and/or verrucate elements along the lipped rays. Proximally the polar surface near the cingulizonate structure bears sparse long spinae between occasional grana and verrucae. Distal face sculptured with mammoid elements. Towards the periphery, verrucae, spinae and bacula are fused to form cristae that sometimes delimit small lumina.
Cristatisporites morungavensis (Dias Fabrício) Picarelli and Dias Fabrício 1990 differs from this species by possessing a more variable sculptured proximal than distal face and a smaller size range of ornamentation elements (major elements 1–2 μm long). *C. microvacuolatus* (Dias Fabrício) Picarelli and Dias Fabrício 1990 differs in that it is comprehensively sculptured on contact areas and has microvacuolate structure of mammoid elements on the distal face.
Distribution: Late Carboniferous, Argentina, first mention. Early Permian, Argentina, Chacoparaná Basin (Archangelsky and Gamerro, 1979).

Genus ***Kraeuselisporites*** Leschik emend. Jansonius 1962

Type species: *K. dentatus* Leschik, 1955.
Botanical affinity: Lycopodiales (Balme, 1970).

Kraeuselisporites volkheimerii Azcuy 1975 (Plate II, 2, 7)
Dimensions (eight specimens): Equatorial diameter 55–80 μm; major elements up to 6 μm long and 5 μm basal diameter.
Remarks: Laevigate proximal face; trilete mark with elevated lips often extending to inner margin of the zona. Entire periphery with scarce spinose elements. Distal exoexine and inner portion of the zona bear mainly discrete (sometimes there are few fused elements) and prominent mammoid projections with stout or curved spinose tips. Wide and thin zona with scattered coni and spinae. Intexine distinct or indistinct.
Distribution: Late Carboniferous, Argentina, Paganzo Basin (Azcuy, 1975b; Ottone, 1989; Limarino and Gutiérrez, 1990; Césari and Bercowski, 1997; di Pasquo and Azcuy, 1997a, 1999a; di Pasquo, 1999).

Genus ***Vallatisporites*** Hacquebard 1957

Type species: *V. vallatus* Hacquebard, 1957.
Botanical affinity: Lycophyta (Scull et al., 1966; Bharadwaj and Venkatachala, 1968; Balme, 1995). Equisetopsida (Balme, 1995).

Vallatisporites vallatus Hacquebard 1957 (Plate II, 11)
Distribution: Mississippian, Canada (Hacquebard, 1957). Early Late Carboniferous, Argentina (Azcuy, 1975b; di Pasquo, 1999), Brazil (Lima et al., 1983; Souza et al., 1993). Early Permian, Brazil (Dias, 1993). This is also a frequently noted, Mississippian or Early Carboniferous, miospore assemblage component from Euramerican microfloras (see Ravn, 1991, p. 95).

Turma **Hilates** Dettmann 1963

Genus ***Psomospora*** Playford and Helby 1968

Type species: P. detecta Playford and Helby, 1968.
Botanical affinity: Hepaticopsida? (see Playford and Helby, 1968).

Psomospora detecta Playford and Helby 1968 (Plate II, 19)
Dimensions (two specimens): Major equatorial diameter 58 μm.
Remarks: The specimen recorded from Tuyunti creek appears to resemble closely the original material described by Playford and Helby (1968).
Distribution: Late Carboniferous-Early Permian, Australia (Jones and Truswell, 1992). Early Late Carboniferous, Australia (Playford and Helby, 1968), Argentina (Azcuy, 1975b), Brazil (Dino and Playford, 1997). Latest Late Carboniferous, Oman and Saudi Arabia (Stephenson and Filatoff, 2000).

Anteturma **Variegerminantes** Potonié 1970
Turma **Saccites** Erdtman 1947
Subturma **Monosaccites** (Chitaley) Potonié and Kremp 1954
Infraturma **Sphaerosacciti** Dibner 1971

Genus ***Schulzospora*** Kosanke 1950

Type species: Schulzospora rara Kosanke 1950.
Botanical affinity: Gymnosperm (Kosanke, 1950). Pteridosperm (*Simplotheca silesiaca* Remy and Remy 1955 from Namurian, see Smith and Butterworth, 1967). Cycadopsida, Lagenostomales (Balme, 1995).

Schulzospora sp. (Plate II, 21)
Description: Monosaccate pollen grain bilateral, trilete, amb oval-subrectangular. Central body fairly distinct, spheroid; trilete rays almost reach its margin. Saccus endoreticulum with large lumina radially elongate, covering the entire surface of the grain. No folds are present.
Dimensions (one specimen): Horizontal diameter 113.4 μm; vertical diameter 82.3 μm; central body diameter 57.5 μm.
Comparisons: *Schulzospora rara* Kosanke 1950 (pl. 13, fig. 8) differs from this specimen in having an oval-elliptical amb with a larger central body that almost reaches the transverse sides of the grain.
Distribution: This form assignable to the genus *Schulzospora* is for the first time recorded from the early Late Carboniferous (≅Namurian-Westphalian, Morrowan or early Bashkirian) of Argentina.

Infraturma **Monopolsacciti** Hart 1965 emend. Dibner 1971
Subinfraturma **Distalsaccini** Dibner 1971

Genus ***Cystoptychus*** Felix and Burbridge 1967 emend.

Type species: *C. velatus* Felix and Burbridge 1967.
Botanical affinity: Gymnosperms (Cordaitalean?).
Emended Diagnosis: Prepollen grains, monosaccate, circular to irregular amb due to secondary folding, originally spheroidal, margin smooth to slightly irregular. Central body circular to subtriangular in polar view, fairly distinctive, smooth. Trilete mark simple, thin, straight, distinctive or obscured by folding, may be closed or open, almost reaching the periphery of the central body. Saccus (sexine) thinner than body (nexine), at-

tached on proximal-equatorial pole and distally loose, e.g. nexine and sexine are separated forming a distal expansion thus, explaining the commonly eccentric positions of the body in respect to the saccus in polar compressions. Seemingly, this expansion is completely filled with sexinous material (alveolate and/or microgranular infrastructure). Due to compression, it commonly displays folds of random distribution but mainly around the attachment zone onto the proximal pole. Polar and laterally compressed specimens are both frequent. Surface smooth. Leptoma absent.
Remarks: The emendation reinterprets the saccus to body attachment, which is only proximal-equatorial and defines a cavity on the distal portion where both lamellae (inner and outer) are separated. Thus, a prepollen condition is established for this type of monosaccate pollen grains, in accordance with Poort et al. (1996).
Comparisons: In the original description of *Nuskoisporites* Potonié and Klaus 1954 or in later emendations to include or to exclude species from the genus (Klaus, 1963; Potonié and Lele, 1961; Lele, 1964; Hart, 1965), an eccentric character of the central body in respect to the saccus and a common presence of secondary folds are frequently observed. In a recent study of the morphology and ultrastructure *Nuskoisporites dulhuntyi* related to the Permian conifer *Ortiseia* Florin, Poort et al. (1997) conclude that this species is regarded as a monosaccoid prepollen because of the absence of a leptoma and the development of an (sub)equatorial expansion. This latter character let distinguish both genera.

Another comparable genus is *Auroraspora* Hoffmeister, Staplin and Malloy, but this differs from *Cystoptychus* because of the presence of ornamentation on the exine surface (exoexine) and the pseudosaccate condition. In a study of Tournaisian-Viséan microfloras from Poland, Turnau (1978) distinguished a new species *Auroraspora panda* from *Cystoptychus velatus* Felix and Burbridge only by their size range. Later, when describing palynofloras from the similar aged Alaskan sequences, Ravn (1991) transferred to *Auroraspora* the species *C. velatus*, thus considering the latter genus a junior synonym of *Auroraspora*. Also, he considered Turnau's species as junior synonym of *Auroraspora velata* (Felix and Burbridge) Ravn. Instead, in this work this combination is not accepted since it is considered that *Cystoptychus* is a pollen genus whereas *Auroraspora* includes trilete, ornamented pseudosaccate spores.

Cystoptychus azcuyi sp. nov. (Plate II, 5, 6, 8, 9, 12, 15, 17)

1999 *Cystoptychus* sp. cf. *C. velatus* Felix and Burbridge; di Pasquo and Azcuy, pl. 1, fig. 7.

Holotype: BAFC-Pl 451(2) U30/0 (Plate II, 6).
Paratypes: BAFC-Pl 451(1) B54/2 (Plate II, 5), BAFC-Pl 453(4) J58/0 (Plate II, 9).
Type locality: Tuyunti creek, Aguaragüe range, Salta province, Argentina (Tupambi Formation).
Derivatio nominis: Dedicated to true but best left out Dr. Carlos Azcuy, who trained several generations of palynologists in Argentina.
Diagnosis: Prepollen monosaccate, trilete; outline subcircular to irregular due to secondary folding. Margin smooth to slightly irregular. Spore body subcircular to subtriangular, fairly distinctive; trilete mark straight, simple and frequently closed, extending nearly to body margin. Sometimes folding obscures it. Saccus attachment to corpus proximal-equatorial, showing a microgranular to microalveolate infrastructure of the sexine. Distal sexine separated from nexine forming a cavity that seems to be filled with a microgranular to microalveolate sexinous material, frequently folded towards the proximal pole. Thus, commonly eccentric positions of the body in respect to saccus in polar compressions are encountered. Relation of the saccus/body radius 1/3. Leptoma absent.
Dimensions (80 specimens): Holotype: major overall equatorial diameter 73 μm; central body diameter 52 μm; maximum saccus width 17 μm. Sintypes: major overall equatorial diameter 50–80 μm; maximum central body diameter 35(44–52)58 μm; maximum saccus width 8(15)17 μm.
Remarks: SEM illustration on Plate III, 8, shows a laevigate ectexine with folds near the central body amb on the proximal face. The specimen figured on Plate III, 6, shows the distal surface where the central body does not appear delineated

because both lamella layers (inner and outer) are separated.

Azcuy and Laffitte (1981) mentioned this species as *Cystoptychus* sp. cf. *C. velatus*, found in samples 1C, 1E and 2B belonging to the upper Tupambi Formation. Both sample sets (see Fig. 2) are correlated on the basis of equivalent palynomorphs content. Recently, in order to illustrate the Late Carboniferous selected miospores of the Macharetí and Mandiyutí Groups from Tarija Basin, a specimen of *C. azcuyi sp. nov.* was also figured as *C. azcuyi* sp. cf. *C. velatus* by di Pasquo and Azcuy (1999a, pl. 1, fig. 7).

Comparisons: *Cystoptychus velatus* Felix and Burbridge (1967, pl. 63, fig. 5) is distinguishable from this species mainly by the triangular gap formed by the open trilete mark and the characteristic saccus folding in one direction. An examination of the original material of *C. velatus* might allow a better comparison. *Auroraspora balteola* Sullivan 1964 (pl. 61, figs. 1–3) also resembles *C. azcuyi* but has a different arrangement of folding; the exine is smooth to finely infrapunctate and has a greater size range (total diameter 85(110)125 µm).

Distribution: This species is here for the first time described from the early Late Carboniferous (≅Namurian-Westphalian, Morrowan or early Bashkirian) of Argentina.

Infraturma **Dipolsacciti** Hart emend. Dibner 1971

Genus ***Meristocorpus*** Playford and Dino 2000

Type species: *M. explicatus* Playford and Dino 2000b.

Botanical affinity: Gymnosperm.

Meristocorpus sp. (Plate II, 10)

Description: Monosaccate bilateral, oval in overall shape. Central body well defined subhexagonal, bearing proximally five horizontal parallel to subparallel, some bifurcate striations extending from one end to the other. Laesurae not visible. Distal attachment zone of saccus to body associated with two vertical folds that defined a more or less broadly rectangular cappula. Saccus finely intrareticulate.

Dimensions (two specimens): Horizontal equatorial diameter of the grain 99–174 µm, vertical 60–106 µm; central body horizontal diameter 51–93 µm, vertical 52–87 µm.

Comparisons: This species differs from others of the genus because it has few striae on the proximal face, two vertical folds delimiting a rectangular cappula and a subhexagonal body shape.

Distribution: The genus and its species are for the first time registered from the early Late Carboniferous (≅Namurian-Westphalian, Morrowan or early Bashkirian) of Argentina.

Turma **Plicates** (Naumova) Potonié 1960
Subturma **Praecolpates** Potonié and Kremp 1954

Genus ***Schopfipollenites*** Potonié and Kremp 1954

Type species: *Schopfipollenites ellipsoides* (Ibrahim) Potonié and Kremp 1954.

Botanical affinity: Pteridospermophyta, Medullosaceae (Florín, 1937; Schopf et al., 1944; Potonié and Kremp, 1954, 1956; Delevoryas, 1964; Taylor, 1978; Millay et al., 1978; Taylor and Rothwell, 1982; Stewart and Rothwell, 1993; see also Balme, 1995). Cycadopsida, Trigonocarpales (Balme, 1995).

Generic remarks: See Potonié and Kremp (1954) and Smith and Butterworth (1967). See also in Balme (1995, p. 188) more detailed explanation about grain morphology and ultrastructure variability (related to in situ and dispersed pollen condition), taken from several previous researches (e.g. Millay et al., 1978; Taylor, 1978; Taylor and Rothwell, 1982).

Schopfipollenites ellipsoides (Ibrahim) Potonié and Kremp 1954 (Plate II, 16)

1962 *Schopfipollenites signatus* Wilson, pl. 1, fig. 10.
1966 *Schopfipollenites* sp. A Habib, pl. 109, fig. 10.
1967 *Monoletes ovatus* Schopf; Felix and Burbridge, pl. 63, figs. 1, 2.
1967 *Schopfipollenites* sp. Barss, pl. 21, fig. 6; pl. 24, fig. 14; pl. 27, fig. 23; pl. 31, fig. 14; pl. 33, fig. 16.
1980 *Schopfipollenites* sp. Attar et al., pl. 4, figs. 6, 8.
1999 *Schopfipollenites ellipsoides* var. *corporeus* Neves; di Pasquo and Azcuy, pl. 1, fig. 8.

For additional synonymy see Smith and Butterworth (1967, p. 310).
Description: Pollen grain praecolpate, bilateral symmetry, amb oval, margin smooth. Central body (endexine) follows the amb; monolete mark simple, straight or bent, extends around 1/2 corpus diameter. Exoexine infragranulate-alveolate, relatively thin (3–6 μm width). Distal face with one or two longitudinal folds.
Dimensions (four specimens): Maximum diameter 122–98 μm; minor diameter 83.5–69.6 μm.
Remarks and comparisons: Smith and Butterworth (1967) proposed that specimens with an inner lamellae developed are best assigned as *Schopfipollenites ellipsoides* var. *corporeus* defined by Neves (1961). On the other hand, Taylor (1978) and Taylor and Rothwell (1982), amongst others, stated that mainly lamellar differentiation, development of distal grooves (which are generally obscured by folding) and grain size are function of maturity and cannot be reliably used for systematic purposes. The specimens described herein are very similar to those illustrated by Smith and Butterworth (1967, pl. 27, fig. 2), but being smaller in size. The specimens described as *Schopfipollenites signatus* Wilson (1962, pl. 1, fig. 10), *Schopfipollenites* sp. A Habib (1966, pl. 109, fig. 10), *Monoletes ovatus* Schopf by Felix and Burbridge (1967, pl. 63, figs. 1, 2), *Schopfipollenites* sp. Barss (1967, pl. 21, fig. 6, pl. 24, fig. 14, pl. 27, fig. 23, pl. 31, fig. 14, pl. 33, fig. 16) and *Schopfipollenites* sp. Attar et al. (1980, pl. 4, figs. 6, 8), are fully comparable with those described and illustrated by Smith and Butterworth (1967, pl. 27, fig. 2), so they are considered junior synonyms of *Schopfipollenites ellipsoides*.
Distribution: Widely registered in the Euramerican Province spanning Late Viséan to Stephanian (Staplin et al., 1967; Balme, 1995). Some Late Carboniferous records are from Westphalian B-D, Germany (Potonié and Kremp, 1954; Bhardwaj, 1957a,b), Namurian B-Westphalian D, England (Neves, 1961; Smith and Butterworth, 1967; Turner and Spinner, 1993), Westphalian D, USA (Habib, 1966), Westphalian-Stephanian, Canada (Barss, 1967), Westphalian, Canada (Lyons et al., 1997), Pennsylvanian, USA (Felix and Burbridge, 1967), Late Serpukhovian, Libya (Attar et al., 1980; Massa et al., 1980; Coquel et al., 1988), Namurian, Saudi Arabia (Clayton, 1995), Late Carboniferous, Argentina (Mandiyutí Group, di Pasquo and Azcuy, 1997a; Macharetí Group, Tupambi Formation, di Pasquo and Azcuy, 1999a). Others are from Lower Permian, Brazil (Dias, 1993), Late Permian, USA (Wilson, 1962).

5. Biostratigraphy

5.1. Introduction

The Interval Zone or Lineage Zone based on the appearance of two successive lowest occurrence single species, as accepted by the International Commission on Stratigraphic Classification of International Union of Geological Sciences and summarised by Christopher and Goodman (1996) and Stover et al. (1996), is followed herein. The Carboniferous miospore zonation of Western Europe constitutes an example of this biostratigraphic scheme. This is broadly recognised as

Table 1
Percentages of indigenous and reworked palynomorph major groups, based on the count of approximately 200 specimens per sample

Assemblage	Indigenous			Reworked	
Sample	spores (%)	pollen grains (%)	algae (%)	spores (%)	acritarchs (%)
453	19	10	3	21	47
451	34	29	1	21	15
1C	47	23	0	19	11
1E	54	22	1	10	13
2B	23	16	1	43	18
1263	48	44	2	2	4

For other references see Table 2.

Table 2
Quantitative distribution of the species recognised in samples from Tuyunti creek outcrop and Fortín Alegre borehole, Salta Province, Argentina

Localities	Tuyunti Creek outcrop					F. Alegre borehole
Lithostratigraphic unit	Tupambi formation (samples, BAFC-Pl)					
Species (Plate, Fig.)	453	451	1C[b]	1E[b]	2B[b]	1263[c]
Apiculatasporites caperatus (Plate I, 16)	C	C	C	C	C	C
Apiculatasporites parviapiculatus (Plate I, 19)	C	S	C	C	S	
Apiculiretusispora alonsoi (Plate I, 3, 7)		C	C	S	S	
Calamospora hartungiana (Plate I, 1, 4)	S	C	C	C	C	C
Crassispora kosankei[a] (Plate I, 12, 14, 15, 17, 18, 20–22; Plate III, 1–3)	A	A	A	A	A	A
Cristatisporites rollerii (Plate I, 23; Plate II, 1)	S	S	S	S	S	S
Cristatisporites saltitensis (Plate II, 3)		S				
Cristatisporites sp. B Archangelsky and Gamerro (Plate II, 4)		S				
Cristatisporites stellatus (Plate I, 24)		S	C			
Granasporites medius (Plate I, 5, 8, 9; Plate III, 4, 7)	C	A	A	A	A	A
Granulatisporites parvus (Plate I, 10)	S					C
Granulatisporites varigranifer (Plate I, 13)				S		
Kraeuselisporites volkheimerii (Plate II, 2, 7)		C	S			
Punctatisporites glaber (Plate I, 2)		S	C		S	
Raistrickia sp. cf. *R. crinita*[a] (Plate I, 11)			S			
Vallatisporites vallatus (Plate II, 11)		S				
Waltzispora polita (Plate I, 6)		S			S	
Caheniasaccites flavatus		S	S	S	S	
Cannanoropollis densus	S				S	
Cannanoropollis janakii		S	S		S	
Cannanoropollis triangularis		S			S	
Circumplicatipollis plicatus		S				
Circumplicatipollis stigmatus		S				
Cystoptychus azcuyi[a] (Plate II, 5, 6, 8, 9, 12, 15, 17; Plate III, 5, 8)	C	A	C	A	A	A
Plicatipollenites malabarensis	S	S	S	S		S
Plicatipollenites trigonalis		S				
Potonieisporites barrelis		S	S	S		
Potonieisporites brasiliensis		S				
Potonieisporites congoensis		S		S	S	S
Potonieisporites densus		S	S	C	S	
Potonieisporites magnus	S	S		C	S	C
Potonieisporites neglectus (Plate II, 13)	S	S	C	C		C
Potonieisporites novicus (Plate II, 14, 18; Plate III, 5)	S	S	S		S	C
Potonieisporites triangulatus		S				
Schopfipollenites ellipsoides (Plate II, 16)		S			S	C
Schultzospora sp.[a] (Plate II, 21)		S				
Meristocorpus sp.[a] (Plate II, 10)		S	S	S	S	
Botryococcus braunii (Plate II, 20, 22)	C	S			S	
Psomospora detecta (Plate II, 19)		S			S	

The frequency of each taxa is calculated over approximately 200 specimens by sample. The percentage abundance ranges, expressed in letters, are the following: S, scarce, $<1.5\%$; C, common, 1.5–5.0%; A, abundant, $>5.0\%$. The species are in alphabetical order arranged into three major groups, spores, pollen grains and algae.

[a] Cited for the first time in the Argentines.

[b] Samples restudied herein from Azcuy and Laffitte (1981).

[c] Core sample.

being useful for long distance correlation by many authors and has zonal boundaries based on certain taxa first appearance datum (FAD) that may only occur in small numbers (Clayton, 1996).

The terms biozone and palynozone are considered synonymous and both are used in the sections covering biostratigraphy.

5.2. *Crassispora kosankei–Cystoptychus azcuyi* FAD palynozone

Crassispora kosankei and *Cystoptychus azcuyi* are the proposed formal palynomorph markers because they first appear in the base of the biozone and have a fairly wide geographic distribution (two localities presented herein and other records in outcrops from Bolivia yet unpublished). They are also morphologically easily recognisable, the most abundant taxa in both localities (Table 2) and are stratigraphically restricted to the assemblages found in the Tupambi Formation.

Stratotype section: The Fortín Alegre (YPF St.FA x-1) borehole is the selected reference section. The sample BAFC-Pl 1263 (2818 m) belongs to the Tupambi Formation, more precisely the 'pelitic or Itacua' member after Villa et al. (1984; Figs. 2A,B). Although the detailed study of the sample BAFC-Pl 1264 (2975 m) is outside the scope of this work, its preliminary investigation suggests a different microfloral composition, without pollen, *Botryococcus* and resin debris. The absence of all these elements would indicate at least an age not younger than latest Devonian. Moreover, as it contains *Grandispora* spp., *Verrucosisporites* spp. and *Biharisporites* sp., even without acritarchs, it is tentatively assigned Middle to Late Devonian age. Between both productive levels (embracing 157 m thickness) in the borehole, it would be necessary to accommodate the latest Devonian unconformity (Fig. 2B; see also above), but further study should be necessary to refine this datum.

Also, this palynozone is identified in at least two levels of the Tuyunti creek section (Figs. 1 and 2A), belonging to the upper Tupambi Formation.

5.3. Assemblage characteristics

5.3.1. Composition of the assemblage

Two groups of palynomorphs based on their probable age are recognized: (a) the one autochthonous component, contemporary with the deposition of the Upper Carboniferous rocks, composed of pollen grains, spores and algal remains and (b) an allochthonous component, composed of recycled spores, acritarchs and prasinophytes derived from the erosion of Devonian and Lower Carboniferous rocks.

Within the autochthonous group, 39 species were determined of which 17 belong to trilete spores, 19 are monosaccate pollen grains, one of which is striated (*Meristocorpus* sp.), one species of a praecolpate pollen grain (*Schopfipollenites ellipsoides*), one hilate spore (*Psomospora detecta*) and the chlorophyte *Botryococcus braunii*. The percentages of the major morphological groups, autochthonous and reworked, in the studied samples are shown in Table 1. The quantitative analysis is based on the counts of around 200 specimens per sample. The quantitative distribution of the autochthonous species is shown in Table 2, where also the species for the first time recorded in Argentina are indicated with an asterisk. *Crassispora kosankei* and *Cystoptychus azcuyi* are restricted to this unit and are the dominant forms of the assemblages, ranging from 15 to 30% based on the total amount of species of the autochthonous group. Also, *Granasporites medius* is frequently present in the assemblages.

Azcuy and di Pasquo (2000) presented a revision of some monosaccate pollen genera and its species found in the Mandiyutí Group. Almost the same monosaccate species are also abundantly recorded in the Macharetí Group, chiefly in the Tupambi Formation, where they range around 10 to 45% based on the total amount of palynomorphs per sample (Table 1). Such differences of pollen grains relative abundance within this biozone represent some changes in local palaeoenvironmental conditions throughout time and space rather than implying some biostratigraphic significance.

The records of algal remains are only used as a palaeoecological indicator, since the biostratigraphic range data are limited and doubtful, except for the green alga *Botryococcus*, which first appears at the beginning of the Carboniferous (Colbath and Grenfell, 1995).

Additionally, less abundant but nevertheless characteristic species that characterise this biozone are *Cristatisporites rollerii, C. stellatus, C. saltitensis, Kraeuselisporites volkheimerii, Apiculatasporites parviapiculatus, A. caperatus, Granulatisporites parvus, Apiculiretusispora alonsoi, Waltzispora polita, Punctatisporites glaber, Calamospora hartungiana, Schopfipollenites ellipsoides* and *Meristocorpus* sp. Moreover, there are seven species which are restricted to this palynozone (i.e. they disappear in the overlying stratigraphic units, Itacuamí and Tarija Formations, Fig. 2B), such as *Raistrickia* sp. cf. R. *crinita, Cristatisporites rollerii, C. saltitensis*, *Cristatisporites* sp. B Archangelsky and Gamerro, *Psomospora detecta*, *Meristocorpus* sp., *Schulzospora* sp. Other species may or may not diminish its frequency in the succeeding assemblages, recorded in the overlying Itacuamí and Tarija Formations (di Pasquo, 1999).

5.3.2. Botanical affinities

Based on the known generic affinities of palynomorphs, parent vegetation composed mainly of Cordaitales, Coniferales and Pteridophytes can be recognized. *Cystoptychus, Schulzospora, Cannanoropollis, Circumplicatipollis, Caheniasaccites, Plicatipollenites* and *Potonieisporites* are monosaccate pollen grains linked with the Gymnosperms (cordaitalean and coniferalean). *Schopfipollenites* is praecolpate pollen related to the Medullosaceae in the Northern Hemisphere palynofloras. Up to now, Medullosaceae remains seemingly have not been found in the Late Carboniferous paleofloristic assemblages from Argentina. *Crassispora, Granasporites, Cristatisporites*, *Kraeuselisporites* and *Vallatisporites* are spore genera related to the Lycophyta, *Punctatisporites*, *Raistrickia, Apiculatasporites, Granulatisporites* and *Verrucosisporites* are linked with the ferns, *Calamospora* is identified as sphenopsid and *Botryococcus* correspond to green Algae. The latter species is mainly found in continental bodies of water (e.g. Batten, 1996). This plant community is typical of lacustrine or fluvio-deltaic palaeoenvironments in the Late Carboniferous basins of Argentina. An extended palaeoenviromental interpretation of the Tupambi Formation, based on these palynologic results and other evidences, will be addressed in another paper.

6. Age, biostratigraphic and paleogeographic importance

An early Late Carboniferous age, approximately equivalent to the late Namurian, early Morrowan or early Bashkirian is assigned to the palynomorphs assemblages recovered from two sections belonging to the Tupambi Formation (surface and subsurface) located in northern Salta Province, Argentina (Figs. 1 and 2A,B). This age and other biostratigraphic and paleogeographic considerations are based on the following arguments:

(1) The appearance of the monosaccate pollen grains related to the cordaitalean and coniferalean gymnosperms (Stockey, 1981; Taylor and Taylor, 1993; Ouyang, 1996) is recorded in the late Early Carboniferous. Clayton et al. (1990), Clayton (1996) and Ouyang (1996) summarise the palynologic events of biostratigraphic importance at world level for the Mississippian (Early Carboniferous). These authors conclude that the first appearance of scarce species of monosaccate pollen grains such as *Florinites* spp. and *Potonieisporites elegans* (Wilson and Kosanke) Wilson and Venkatachala, occur in the early Namurian or Serpukhovian. So, they are at first scarce elements mainly in the Euramerican and Russian microfloras, but a little later they appear around basal Late Carboniferous elsewhere in the world (Butterworth, 1969; Clayton et al., 1990; Clayton, 1996; Owens, 1996). Despite this slight diachronism cited above, abundant evidence of assemblages typically dominated by monosaccate pollen are clearly recorded around the latest Namurian or early Westphalian of Europe (Neves, 1961; Loboziak, 1974; Clayton et al., 1977), North America (Peppers, 1996), Canada (Barss, 1967; Hacque-

bard, 1997), Australia (Kemp et al., 1977; Powis, 1984; Jones and Truswell, 1992), North Africa and Arabian Peninsula (Attar et al., 1980; Massa et al., 1980; Coquel et al., 1988; Loboziak and Clayton, 1988; Clayton, 1995; Owens et al., 2000), Russia (Teteriuk, 1976; Owens et al., 1978); China (Zhou, 1994), South America (Azcuy, 1975a,b; Limarino and Gutiérrez, 1990; Melo et al., 1999; Playford and Dino, 2000b; also this assemblage). Therefore, the presence of large number and great diversity of monosaccate species registered in the assemblages from the Tupambi Formation, confirm an age not older than basal Late Carboniferous (≅Namurian B/early Morrowan/early Bashkirian).

(2) The presence of *Punctatisporites glaber*, *Waltzispora polita, Vallatisporites vallatus, Schulzospora* sp., *Schopfipollenites ellipsoides*, also endorses an age close to the boundary between the Early and Late Carboniferous. In the Northern Hemisphere floras these species frequently appear in deposits of the latest Early Carboniferous (late Visean–early Namurian), declining in abundance toward this boundary (Coquel et al., 1988; Owens, 1996). Moreover, the absence of striate and non-striate bisaccate pollen grains (though they could appear in very small numbers) is in accord with a late Namurian age (see Owens, 1996, p. 603; Ouyang, 1996, p. 23; Loboziak et al., 1997, p. 470; Melo et al., 1999, p. 21; Playford and Dino, 2000b, p. 129; Owens et al., 2000, p. 162).

(3) The stratigraphic ranges of *Crassispora kosankei*, essentially spanning the Namurian B-European Westphalian interval (Clayton et al., 1977) and *Granasporites medius*, widely known from Westphalian A to Stephanian strata of Europe and Lower and Middle Pennsylvanian strata of North America (Ravn et al., 1986), suggest an age not older than Namurian B for the assemblage. This is in accord with the age indicated by the abundance and diversity of monosaccate pollen grains.

(4) Trilete spores like *Cristatisporites rollerii, C. saltitensis, C. stellatus, Kraeuselisporites volkheimerii, Apiculatasporites parviapiculatus, A. caperatus, Apiculiretusispora alonsoi*, amongst others, make their first appearance in this palynozone at the Tarija Basin. They are widely represented in the Late Carboniferous assemblages from Argentina (see 'distribution' section above), being characteristic elements in the *Ancistrospora* palynozone that Azcuy and Jelín (1980) defined from the early Late Carboniferous Paganzo Basin strata.

(5) The Tupambi Formation is stratigraphically the lowest unit of the Macharetí Group (Fig. 2B). The latter is succeeded by the Mandiyutí Group, which is assigned to the late Upper Carboniferous (probably latest Westphalian to Stephanian), based on palynologic data (di Pasquo and Azcuy, 1997a,b, 1999a,b; di Pasquo, 1999; Azcuy and di Pasquo, 2000; di Pasquo et al., 2001). The stratigraphic position of the Tupambi Formation thus supports the early Late Carboniferous age for the palynozone herein proposed.

(6) Another approach used in North America to recognize the limit between two Subsystems (or Series) is based on the identification of a significant unconformity, which is represented by a change from carbonate to clastic (mainly shales) sedimentation. In Gondwana this unconformity has also been recorded in Namurian A or late Viséan-Serpukhovian (Saunders and Ramsbottom, *in* Isaacson and Martínez, 1995), which is related with two global events, a major regression and the onset of the main glacial episode (Veevers and Powell, 1987). In the Argentinean Tarija Basin, some authors (e.g. Starck et al., 1993b) report an unconformity between the Tupambi and Los Monos/Iquirí Formations (Fig. 2B). In some localities of southern Bolivia this unconformity is mainly registered between the Itacua (= Saipurú) and Tupambi Formations (Fig. 2B). The former is attributed to the Early Carboniferous on the basis of palynologic data (see discussion in di Pasquo and Azcuy, 1997b).

This erosive and angular unconformity at the base of the Tupambi Formation is linked with the Chanic orogeny; a considerable package of Devonian and Lower Carboniferous strata were eroded and created a paleorelief prior to the deposition of the Late Palaeozoic sediments (Starck et al., 1993a,b). Glacial processes that occurred early during the Carboniferous would have incised these paleovalleys. The retreat of the ice would have generated new ecological niches which were colonised by a new microfloral dominated mainly by Gymnosperms (Cordaitales and Coniferales), Lycophytes, Sphenophytes and Pterophytes (ferns) around predominantly humid palaeoenvironments (mainly deltaic and lacustrine depocentres). The presence of *Botryococcus* supports a continental origin for depocentres (see 'botanical affinities' section above). Rivers brought reworked palynomorphs (see Table 1 and Appendix 1) to depocentres. This evidence supports the idea of fluvial (and perhaps glacial) erosion of the Middle and Late Devonian Michicola Arc strata, placed in the Southeast border of the basin during the Late Carboniferous (Starck et al., 1993a,b; di Pasquo and Azcuy, 1997b; Azcuy and di Pasquo, 1999).

(7) The comparison with other microfloras (mainly from South America, Africa, Libya, Saudi Arabia, India and Australia) supports the Gondwanan floristic affiliation of this biozone assemblage. However, several genera have not previously been recorded from the Late Palaeozoic deposits of southern South America, such as *Crassispora, Granasporites*, *Schulzospora* and *Cystoptychus*. They are all common floral elements in the Euramerican Province during the Late Carboniferous (see 'distribution' section above). Thus, it is evidence of a relative floral interchange between western parts of Laurasia and Gondwana. This microfloral interchange could be explained, as the proximity of both landmasses would reach a maximum until their collision during the Westphalian (Scotese and McKerrow, 1990). Another explanation given by Kremp (1977) is based on the migration of landplants related to the constant northward movement of Pangae during the Late Carboniferous, which caused a constant southward shift of the climate zones. Therefore, this land-displacement forced plant and animal communities into a continuing southward migration in order to maintain nearly the same palaeoenvironment conditions. This concept also explains some diachronism in the first appearances of pollen grains in the global terrestrial floras (Ouyang, 1996).

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Appendix 1. Composite list of fossil taxa identified

Indigenous palynomorphs:

Spores

Apiculatasporites caperatus Menéndez and Azcuy 1969

Apiculatasporites parviapiculatus Azcuy 1975

Apiculiretusispora alonsoi Ottone 1989

Calamospora hartungiana Schopf *in* Schopf, Wilson and Bentall 1944

Crassispora kosankei (Potonié and Kremp) Bhardwaj emend. Smith and Butterworth 1967

Cristatisporites rollerii Ottone 1989

Cristatisporites saltitensis Ottone 1989

Cristatisporites stellatus (Azcuy) Limarino and Gutiérrez 1990

Cristatisporites sp. B Archangelsky and Gamerro 1979

Granasporites medius (Dybová and Jachovicz) Ravn et al. 1986

Granulatisporites parvus (Ibrahim) Schopf, Wilson and Bentall 1944

Granulatisporites varigranifer Azcuy 1975

Kraeuselisporites volkheimerii Azcuy 1975

Punctatisporites glaber (Naumova) Playford 1962

Raistrickia sp. cf *R. crinita* Kosanke 1950
Vallatisporites vallatus Hacquebard 1957
Waltzispora polita (Hoffmeister, Staplin and Malloy) Smith and Butterworth 1967

Pollen grains
Caheniasaccites flavatus Bose and Kar emend. Azcuy and di Pasquo 2000
Cannanoropollis densus (Lele) Bose and Maheshwari 1968
Cannanoropollis janakii Potonié and Sah 1960
Cannanoropollis triangularis (Mehta) Bose and Maheshwari 1968
Circumplicatipollis plicatus Ottone and Azcuy 1988
Circumplicatipollis stigmatus (Lele and Karim) Ottone and Azcuy 1988
Cystoptychus azcuyi sp. nov.
Plicatipollenites malabarensis (Potonié and Sah) Foster 1975
Plicatipollenites trigonalis Lele 1964
Potonieisporites barrelis Tiwari 1965
Potonieisporites brasiliensis (Nahuys, Alpern e Ybert) Archangelsky and Gamerro 1979
Potonieisporites congoensis Bose and Maheshwari 1968
Potonieisporites densus Maheshwari 1967
Potonieisporites magnus Lele and Karim 1971
Potonieisporites neglectus Potonié and Lele 1961
Potonieisporites novicus Bhardwaj 1954 emend. Poort and Veld 1997
Potonieisporites triangulatus Tiwari 1965
Schopfipollenites ellipsoides (Ibrahim) Potonié and Kremp 1954
Schulzospora sp.
Meristocorpus sp.

Algae
Botryococcus braunii Kützing 1849

Reworked palynomorphs:

Spores
Acanthotriletes denticulatus Naumova 1953
Acinosporites eumamillatus Loboziak et al., 1988
Acinosporites ledundae Ottone 1996
Ancyrospora langi (Taugourdeau-Lantz) Allen 1965
Apiculiretusispora brandtii Streel 1964 (= *A. nitida* Owens 1971)
Auroraspora macra Sullivan 1968
Auroraspora solisorta Hoffmeister, Staplin and Malloy 1955
Biharisporites quadrosii Daemon 1974
Camarozonotriletes antiquus Kedo 1955
Dictyotriletes emsiensis (Allen) McGregor 1973
Emphanisporites annulatus McGregor 1961
Geminospora lemurata Balme 1962 emend. Playford 1983
Grandispora inculta Allen 1965
Grandispora mammillata Owens 1971
Grandispora protea (Naumova) Moreau-Benoit 1980
Grandispora pseudoreticulata (Menéndez and Pöthe de Baldis) Ottone 1996
Grandispora permulta (Daemon) Loboziak, Streel and Melo 1999
Grandispora spp.
Pustulatisporites sp. cf. *P. gibberosus* (Hacquebard) Playford 1963
Retusotriletes crassus Clayton et al. 1980
Retusotriletes incohatus Sullivan 1968
Samarisporites triangulatus Allen 1965
Verrucosisporites scurrus (Naumova) McGregor and Camfield 1982

Prasinophyceae
Cymatiosphaera pavimenta (Deflandre) Deflandre 1954
Dictyotidium variatum Playford 1977
Duvernaysphaera angelae Deunff 1964
Duvernaysphaera tenuicingulata Staplin 1961
Duvernaysphaera tessella Deunff 1964
Hemiruptia legaultii Ottone 1996
Leiosphaeridia spp.
Maranhites brasiliensis Brito 1965 emend. Burjack and Oliveira 1989
Maranhites insulatus Burjack and Oliveira 1989
Maranhites lobulatus Burjack and Oliveira 1989
Maranhites mosesii (Sommer) Brito emend. Burjack and Oliveira 1989
Polyedryxium cuboides Deunff 1955
Polyedryxium decorum Deunff 1955
Polyedryxium pharaonis Deunff ex Deunff 1961
Polyedryxium simplex Deunff 1955
Polyedryxium sp. cf. *P. talus* Deunff 1966

Pterospermella solis Wicander 1974
Pterospermella tenellula Playford 1981

Algae
Chomotriletes bistchoensis Staplin 1961
C. multivitattus Playford 1978
Petrovina connata Oliveira and Burjack 1996
Quadrisporites granulatus (Cramer) Ströther 1991
Quadrisporites variabilis (Cramer) Ottone and Rossello 1996

Acritarcha
Ammonidium garrasinoi Ottone 1996
Arkonites bilixus Legault 1973
Baltisphaeridium sp. Ottone 1996
Bimerga bensonii Wood 1995
Crucidia camirense (Lobo Boneta) Ottone 1996
Dactylofusa fastidiona (Cramer) Eisenack et al., 1976
Estiastra barbata Downie 1963
Evittia somerei Brito 1967
Exochoderma arca Wicander and Wood 1981
Exochoderma triangulata Wicander and Wood 1981
Gorgonisphaeridium canningense Colbath 1990
Gorgonisphaeridium discissum Playford 1981
Gorgonisphaeridium sp. Ottone 1996
Hapsidopalla exornata (Deunff) Playford 1977
Multiplicisphaeridium ramispinosum Staplin 1961
Multiplicisphaeridium irregularis Staplin, Jansonius and Pocock 1965
Muraticavea munificus Wicander and Wood 1981
Stellinium micropoligonale (Stockmans and Willière) Playford 1977
Stellinium octoaster (Staplin) Jardiné et al. 1972
Tunisphaeridium caudatum Deunff and Evitt 1968
Umbellasphaeridium saharicum Jardiné et al. 1972
Verhyachium colemanii Playford 1981
Verhyachium downiei Stockmans and Willière 1962
Verhyachium lairdii Deflandre 1946 ex Deunff 1959
Verhyachium polyaster Staplin 1961
Verhyachium trispinosum (Eisenack) Deunff 1954

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